North Carolina Department of Transportation

The Catalyst

Fall 1995

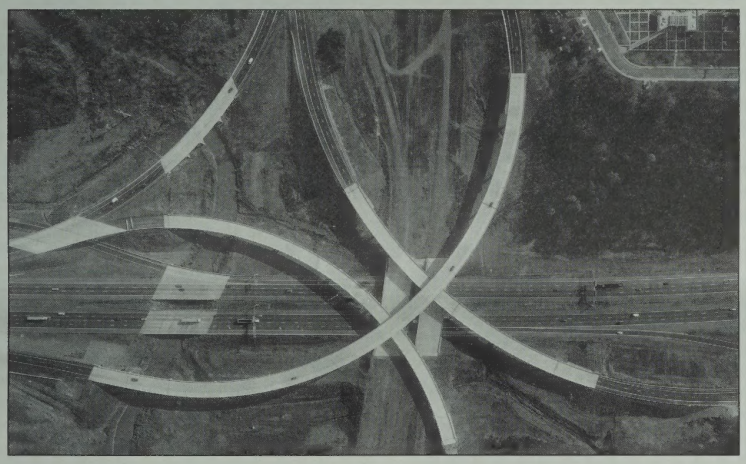
A Newsletter of the Research & Development Unit

Research pays off

Bridge Management System:

A Highly Progressive Development and Successful Experience

Pat Strong



Federal Highway Administration rules issued on March 2, 1993, prescribed specific requirements and standards for the establishment and operation of a management system for North Carolina bridges on and off federal aid highways. As this regulation was issued, the North Carolina Department of Transportation was close to immediate compliance. This resulted from the department's commitment during the preceding twelve years to formal research efforts to develop a completely functional bridge management system. In fact, North Carolina's bridge management system served as a resource and a guide to many other states during the interval to full compliance with this regulation on January 1, 1995. This aspect was clear from the similarities observed between mandatory features cited in the federal regulation and those that had already been developed in North Carolina's system. Examples of the similarities included: (1) a computerized database and an ongoing program for the collection and maintenance of the inventory, inspection, cost, and supplemental data as required by the mandatory national bridge inventory requirements, (2) a computer model for applying network level analyses and optimization techniques to this national bridge inventory, and (3) a methodology for monitoring the status of maintenance, rehabilitation and

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Five new research projects launched

Moy Biswas and Mike Stanley

Beginning July 1, 1995 (Fiscal Year 1996), NCDOT launched five new contract research projects engaging a number of faculty members from institutions of the University of North Carolina System. In the following, you will find brief descriptions of these new contract research projects.

PROJECT 96-1:
Remote Sensing of Mobile Source Air Pollutant Emissions

Background: Highway vehicles are a major emission source for several harmful pollutants. As a result of increased regulations and improved technology, the total emissions from motor vehicles have declined. However, these emissions continue to comprise a substantial portion of national emission inventory. Especially, emissions from so called "Non-controlled" vehicles remain a continued source of concern. The class of "Non-controlled" vehicles includes school buses, service fleets, emergency medical vehicles, fire service equipment and law enforcement vehicles.

Research objectives: The primary research objective will be to perform on-road remote sensing of non-controlled

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replacement actions and a procedure for updating the database when such actions are taken. North Carolina's preceding experience was not unique. In 1988, as a joint engineering venture, the Federal Highway Administration and the California Department of Transportation began to develop the PONTIS system. A limited number of other states had also proceeded to develop budget allocation systems from the national bridge inventory data. Nevertheless, the similarities of features remained apparent. The network level analyses contained in North Carolina's system covered policy, planning, and programming issues for the entire statewide bridge inventory or for selected field division components. The optimization techniques covered budgeting procedures to optimally distribute the department's limited bridge funds among alternative actions over selected short term and long term periods.

The history of this accomplishment was marked with clear vision and steady, persistent efforts. The bridge management system development in North Carolina was initiated during 1981 with the NCDOT staff's realization that the national bridge inventory data requirements and the service ratings for structural sufficiency and functional adequacy together were inadequate for resolving bridge funding decisions. A contract study was funded by the Department under the direction of Drs. David Johnston and Paul Zia at North Carolina State University to examine the more effective use of this data and the rating procedure. The 1984 published findings from this study reported that a comprehensive system was needed to evaluate bridge conditions and needs based on specified levels-of-service and funding priorities. A long range goal was established to develop a maintenance, rehabilitation, and replacement priority system for bridges and to include a capability for estimating future funding needs.

Having established this long range goal, the department began in July 1985 a sustained effort to support further developmental research under Dr. Johnston's direction. A series of four consecutive studies was undertaken through 1994 to complete the development of the bridge management system. There were three underlying objectives common to these additional studies which addressed the ultimate functionality of this system: (1) capability to assess the optimum timing and selection for maintenance, rehabilitation, and replacement actions at the individual bridge level and to annually predict future system-wide funding needs, (2) capability to determine the optimum use of constrained budgets and to annually predict the resulting impact of system-wide performance in terms of bridge element condition deterioration, load capacity condition, and increasing user costs, and (3) relevance as to real user costs and to engineering based levels-of-service.

Early progress was reported in November 1985 with the development of a mathematical algorithm for determining bridge maintenance needs as based on level-of-service concepts. As reported in a progressive manner in September 1987, this analytical capability was extended to encompass bridge rehabilitation needs and was broadened to cover more extensive bridge elemental condition data. Relationships were also reported between bridge replacement needs and costs and desirable levels-of-service. A significant milestone was reached in January 1989 with the reporting of the development of the mainframe computer based budget forecasting and allocation algorithm for this system. This reporting illustrated maintenance, rehabilitation and replacement needs for every bridge in the system. Summaries were provided for ten different management strategies over a twenty year service interval with annual budget allocations ranging from $60,000,000 to unlimited funding. For these ten different strategies, the budget forecasting and optimization outputs detailed specific bridge-by-bridge and county-by-county results and the future performance levels of each bridge over the twenty year period. These outputs demonstrated the tremendous versatility of the bridge management system for addressing long term performance and needs. Further refinement of the system was reported by Dr. Johnston in July 1993 with the release of a computerized methodology to formulate routine maintenance and preventative maintenance strategies. As with the previously reported budget allocation techniques, this methodology was illustrated for specific bridge element levels-of-service derived from system-wide conditions. This feature further enhanced the versatility of the bridge management system.

With these timely research results, the bridge management system was certified on December 27, 1994, and was officially integrated into the operations of the Bridge Maintenance Unit. Technical support for source code integrity for the computer program elements has been assigned to the Department's Engineering Automation Unit. The database support responsibility has been assigned to the Department's Management Information Systems Office. The key features in use of the bridge management system in 1995 have included the following: (1) a bridge inventory record significantly expanded beyond the original minimum Federal Highway Administration requirements, (2) detailed bridge maintenance needs identification and reporting from the in-service field inspections, (3) detailed work accomplishment reports generated during the maintenance process, (4) economic assessment of alternatives

for maintenance, rehabilitation and replacement, (5) assessments based on both Department and user costs in conjunction with specific level-of-service criteria, (6) estimation of current backlog of needs and prediction of optimum future needs for bridge maintenance, rehabilitation and replacement improvements, and (7) prediction of future system performance under various levels of constrained funding.

Specific inquiries concerning the use of the bridge management system may be directed to Mr. J. D. Lee, P.E., State Bridge Maintenance Engineer, (919) 733-4362.

Research in progress

Robotics for Bridge Maintenance

Mike Stanley

A research team headed by Dr. Leonhard Bernold, director of the Construction Automation Robotics Laboratory (CARL) at North Carolina State University, is exploring the application of robotics to several bridge maintenance activities, including paint application, removal and washing. These activities have traditionally been performed manually, exposing workers to potentially hazardous conditions. Successful automation of these tasks would considerably reduce the risks and hazards inherent in bridge maintenance activities.

The three-year study, which was initiated in summer 1994, follows on prior development of a bridge paint removal system prototype, with funding from the USDOT. The initial prototype demonstrated the feasibility of paint removal from bridge girders. The current study addresses modification of the prototype to handle paint removal from diaphragms and bearings, and adaptation of the system to the tasks of paint application and spray washing. The investigation is focusing on development and field testing of prototype modifications that will enable the identified maintenance tasks to be performed. Accomplishments during the initial year of the investigation include:

- Design of a lightweight robot arm with a 90-kg capacity
- Design of a new containment enclosure
- Preparation of a demonstration bridge test facility
- Preparation of a spatial positioning system
- Design and installation of a proportional valve system
- Development of a virtual control architecture

Fabrication of the robot arm is underway, with completion of assembly anticipated in late 1995. Efforts over the next several months will concentrate on fabrication of various other elements of the robotic maintenance system, in preparation for further field testing.

Project 95-3: "Robotic System for Bridge Maintenance." The principal investigator is Dr. Leonhard E. Bernold, Associate. Professor, (919) 515-3677, Department of Civil Engineering, North Carolina State University. The project monitor is Jimmy Lee, P.E. (919) 733-4362 and the R&D Unit contact is Mike Stanley, P.E., (919) 715-2463.

SHRP *Corner*

Moy Biswas

The Strategic Highway Research Program (SHRP) was established by the US Congress in 1987 as a five-year, $150 million research program to improve performance and durability of our nation's roads and to make those roads safer for both motorists and highway workers. SHRP, as represented by the original research contracts expired in March 1993. As a result of SHRP, one hundred and thirty products, including new specifications, tests, equipment and procedures emerged. Now, the emphasis is to extract return on the investment, i.e., to implement the SHRP products. This can only be done at the states' level. Indeed, SHRP has been dubbed as States' Highway Research Program.

At the national level, SHRP implementation efforts indicate following levels of priorities: 1) the Pavement and Asphalt, 2) Showcase of significant SHRP products, and 3) Implementation of other SHRP products. NCDOT's effort to implement SHRP products reflects the national pattern and is briefly described next.

1. Long Term Pavement Performance Studies and the SUPERPAVE® Technology:

General Pavement Studies (GPS)

We have 23 GPS sites spread throughout different climatic and geographical regions of the state. These sites are under a regime of regular and scheduled testing and evaluation. Test data are being collected and forwarded to the FHWA-National Information Management System (NIMS).

Specific Pavement Studies (SPS) #2

We have one set of eight sites on the southbound side of the new US-52 near Lexington, NC. These sites are under a regime of regular and scheduled testing and evaluation. Test data are being collected and also forwarded to NIMS.

Seasonal Monitoring

We have two seasonal monitoring sites. One is at the Lexington SPS-2 location mentioned above and the other is located on the northbound side of US-17 near Elizabeth City, NC. Regular evaluation at these two sites started in September 1995. The core experiments and supplementary experiments are likely to continue through August 1999.

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SHRP Corner continued

Specific Pavement Studies (SPS) #9

We have selected a roadway construction project that will include our SPS-9A experiments. The project is on US-1 straddling Lee and Chatham Counties. The project is at its final stage of design, and we are in a very active stage of planning for SPS-9A experiments. We are planning on including nine test sections, as follows:

New construction:

i) NC standard binder and mix
ii) SUPERPAVE Baseline PG-binder and SUPERPAVE mix
iii) SUPERPAVE Alternative PG-binder and SUPERPAVE mix

Overlay over existing pavement:

iv) NC standard binder and mix design
v) SUPERPAVE Alternative PG-binder and SUPERPAVE mix
vi) PG-SBR Polymer modified binder and SUPERPAVE mix
vii) PG-SBS Polymer modified binder and SUPERPAVE mix
viii) Multi-grade binder and SUPERPAVE mix
ix) One of the above three binders and Stone Mastic Asphalt mix

SUPERPAVE® technology:

Through the usage of pooled funds, we have acquired all SHRP products for testing SUPERPAVE binders and one SHRP product (the gyratory compactor) for testing SUPERPAVE mixes. These products are at various stages of implementation and evaluation. The performance of the Bending Beam Rheometer (BBR) for grading binder at low temperature has not been entirely satisfactory. As we plan to incorporate our SUPERPAVE technology in our SPS-9A experiments, we are in the process of acquiring redundant SHRP SUPERPAVE testing products, especially an alternative BBR and also two additional gyratory compactors for field quality assurance and contractor's quality control. At this point the department is committed to implementing the SUPERPAVE technology in our pavement construction program.

2) Showcase of significant SHRP products

In June 1995, NCDOT hosted the Alkali Silica Reactivity (ASR) Showcase in Charlotte. This was the first SHRP product showcase to be staged in the FHWA Region IV. Over 80 people attended the intensive 3-day workshop representing all federal divisions in the region, majority of state highway agencies, the concrete industry and several operational units of NCDOT. NCDOT is implementing the ASR technology in planning, training, operation and research.

3) Implementation of other SHRP products

Our Traffic Engineering Branch has performed limited evaluation of the following SHRP products related to Highway Operations - Work Zone Safety:

i) Work zone intrusion alarms
ii) Temporary positive lane division
iii) Multi-directional barricade signs

Other SHRP products are at various stages of review and evaluation by a number of committees within our operational units.

Newsbrief

Pat Strong, P.E., State Highway Research Engineer, was elected to serve as the Chairman of the AASHTO Region II Research Advisory Committee (RAC-II) for the 1996 through 1998 calendar years. AASHTO Region II is comprised of 12 southeastern states.

New Research Projects continued

vehicles, primarily school buses. The researchers will utilize a state-of-the-art Remote Sensing Device obtained through the courtesy of the Air Quality Section of the North Carolina Department of Environmental Health and Natural Resources.

The methodology developed as the result of the research project will allow NCDOT to gather good information about emissions from non-controlled vehicles. Availability of such information will allow NCDOT to develop emission inventories and appropriate transportation plans.

Funding amount is $39, 362 for one year through June 30, 1996. The principal investigator is Dr. H. Christopher Frey, Assistant Professor, (919) 515-1155, Department of Civil Engineering, North Carolina State University. The project monitor is Dr. Ron Poole, P.E. (919) 733-4705 and the R&D Unit contact is Pat Strong, P.E., (919) 715-2464.

Project 96-2: Laboratory Investigation of Alkali Silica Reactivity

Background: In pavement and bridges made of Portland cement concrete, ASR (alkali-silica reactivity) occurs when silica in the aggregate and alkali in the cement react in the presence of water. The result is a gel-like substance that absorbs moisture and swells, causing the concrete to crack.

NCDOT "discovered" ASR in North Carolina in the spring of 1987. At that time, during the annual FHWA/NCDOT Spring Bridge Review, the crack patterns observed at the NC 24-27 Garrison Bridge over Lake Tillery revealed existence of ASR. The bridge was built in 1977-78 and by 1987 had developed extensive cracking in every component of the bridge structure including components submerged under water.

In 1994, NCDOT initiated a two-year contract research project to investigate the extent of ASR in highway bridges and pavements in North Carolina. Twenty-three structures and pavement

sections were assessed representing aggregates with ranges of reactivity from low to high and cements with ranges of alkali content from low to high. The results of the study indicated that the ASR problem in North Carolina is "significant" but not necessarily "critical." To address this significant ASR situation, NCDOT hosted the FHWA Region IV SHRP-ASR Showcase in June 1995 and effective July 1, 1995, launched this research project on laboratory investigation of ASR.

Research objectives: The research effort will identify those short, medium and long term laboratory test methods that will allow us to evaluate potential alkali silica reactivity in aggregates as well as in concrete. The results of the research will help us to write specifications which allow us to prescribe threshold levels of alkali in cements to be used in conjunction with certain aggregates and will also allow us to prescribe the amount of mineral mitigating agents (e.g., Type F fly-ash) for certain combination of aggregate and cement. The research will correlate results of laboratory tests with those performed on field structures and will assist us in developing a forensic inspection procedure to recognize and confirm existence of ASR in an existing structure and plan for appropriate mitigation.

Funding amount is $94, 546 for two years through June 30, 1997. The principal investigator is Dr. Shuaib Ahmad, P.E., Professor, (919) 515-7738, and the co-principal investigator is Dr. Michael L. Leming, Assistant Professor, (919) 515-7823, Department of Civil Engineering, North Carolina State University. The project monitor is Dick Reaves, P.E., (919) 733-7411 and the R&D Unit contact is Dr. Moy Biswas, P.E. (919) 715-2465.

Project 96-3: "Level-of-Service Assessment for Congested Freeway Sections in North Carolina

Background: Existing procedures included in the 1994 Highway Capacity Manual (HCM) provide only discrete values for level-of-service , i.e., A, B, C, D, E, and F. Within each of the discrete categories, HCM procedures do not evaluate a range. As we attempt to deploy Intelligent Transportation System (ITS) technology to improve conditions in highway sectors that are already highly congested (category F), the present method will not allow us to quantitatively evaluate the improvement of the level-of-service so obtained.

Research objective: Utilizing the traffic flow model in the 1994 HCM, the research will develop procedures that will provide an assessment of range of quality for basic freeway sections in the F category of level-of-service. Success of this research effort will allow us to make rational investment decisions and evaluation regarding deployment of ITS technology.

Funding amount is $47, 801 for one year through June 30, 1996. The principal investigator is Dr. Gary S. Spring, P.E., Associate Professor, (910) 334-7737, Department of Civil Engineering, North Carolina A&T State University. The project monitor is Jimmy Lynch, P.E., (919) 733-3915 and the R&D Unit contact is Pat Strong, P.E. (919) 715-2464.

Project 96-4: Using Advanced Vehicle Monitoring Systems to Extend System Capacity Along North Carolina Freeways

Background: Congestion is an increasingly common problem on urban and suburban freeways in North Carolina. The NCDOT is pursuing a number of activities intended to manage recurring congestion on selected freeway segments. For example, the CARAT (Congestion Avoidance and Reduction for Autos and Trucks) project that is being developed along the I-77 corridor in Charlotte will utilize, on a real-time basis, various ITS technologies to monitor and manage incidents and other flow interruptions. A significant factor in accomplishing such tasks effectively is knowledge of the parameters of traffic flow breakdown and their relationship to possible intervention strategies to delay or preempt the occurrence of such breakdown.

Research objectives: The focus of the study is to investigate parameters of breakdown in traffic flow on the freeways. The research effort will address the feasibility of intervening in the process of traffic flow breakdown, evaluate the characteristics of traffic flow that typically exist immediately prior to a breakdown in the traffic flow, and evaluate the feasibility of using certain momentary characteristics to predict flow breakdown. As a successful outcome of the research, assuming that we will be able to predict breakdown conditions, we should be able to: 1) delay time of breakdown, 2) reduce severity of breakdown, and 3) shorten recovery time.

Funding amount is $69, 214 for one year through June 30, 1996. The principal investigator is Dr. Nagui M. Rouphail, Professor, (919) 515-1154, Department of Civil Engineering, North Carolina State University, and the co-principal investigator is Dr. Ronald G. Hughes, Manager, Human Factors, The University. of North Carolina Highway Safety Research Center. The project monitor is Blake Norwood, P.E., (919) 733-4705 and R&D Unit contact is Mike Stanley, P.E. (919) 715-2463.

Project 96-5: Interpretation of FWD Data when Pavement Layers are not Intact"

Background: An asphalt concrete pavement system needing rehabilitation may either have visible cracks present in the surface layer or the surface layer may show no cracks but underlying layers may have extensive cracks. In either case, for the purpose of designing for rehabilitation, pavement engineers need to know about the extent of cracks

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and the resulting structural implications. The use of a falling weight deflectometer (FWD) is the primary means of evaluating structural conditions of layered pavements. The present method of interpretation of FWD data is based on the assumption that layers are intact. Currently, taking core samples is the only way to determine the presence and extent of cracks in order to decide on milling depths and thickness of asphalt concrete overlay courses for rehabilitation. Availability of methodology for interpretation of deflection data for pavement layer structural conditions in the presence of cracks will save both time and money.

Research objectives: The research will investigate four types of asphalt concrete pavements: 1) Intact surface layer over aggregate base course, 2) Cracked surface layer over aggregate base course, 3) Intact surface layer over asphalt concrete base course, and 4) Cracked surface layer over asphalt concrete base course. The research effort will determine the effects of cracked or broken layers on FWD deflection basin data and develop methods for evaluating existence and extent of cracks. The researchers will also develop methods for determining to which pavement layers a rehabilitation should be directed.

Funding amount is $75, 000 for two years through June 30, 1997. The principal investigator is Dr. Y. Richard Kim, P.E., Associate Professor, (919) 515-7758, and the co-principal investigator is Dr. S. Ranji Ranjithan, Assistant Professor, (919) 515-6979, Department of Civil Engineering, North Carolina State University. The project monitor is Ken Creech, P.E. (919) 250-4094 and the R&D Unit contact is Dr. Moy Biswas, P.E. (919) 715-2465.

About this Publication

The Catalyst, the newsletter of the Research & Development Unit, is an effort to expand the outreach of the Division of Highways interdisciplinary research activities and to enhance the technology transfer process. With the emphasis on applied research as promoted in the 1991 Intermodal Surface Transportation Efficiency Act legislation and with the new directions that surface transportation appears to be headed during the 1990's, the maximization of all research, development and technology transfer results in the Division of Highways is very important. Effective July 1, 1995, the Division of Highways began utilizing a management system for its research and development program. One of the essential requirements for this management system is to improve efforts to track activities, schedules and accomplishments. Reader feedback concerning any newsletter article is strongly encouraged.

Research report copies covering the various contract research studies may be obtained from Ms. Portia McLean at telephone (919)-715-2461.

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